COLOR IMAGE PROCESSING METHOD, COLOR IMAGE PROCESSING APPARATUS, COLOR IMAGE PROCESSING PROGRAM, AND RECORD MEDIUM

The present disclosure relates to the subject matter contained in Japanese Patent Application No.2002-360445 filed on December 12, 2002, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a color image processing technique for converting an input color image signal into a color image record signal of a color printer, etc., and more particularly to a technique for converting an input color image signal into a color image record signal of N or more colors including a solid color (N is an integer of five or more).

2. Description of the Related Art

In a print technique, solid colors provided by primary color ink of red (R), green (G), and blue (B) and fluorescent ink are added to four colors of Y (yellow), M (magenta), C (cyan), and K (black) to perform color reproduction as a technique for representing vivid colors that cannot be reproduced in four-color process print of Y, M, C, and K. As color samples of solid colors, color samples of Pantone and the like are known and about 1000 solid colors are defined.

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However, up to a maximum of eight colors can be printed at the same time on a printer and thus the number of solid colors that can be used is four at the maximum and is a very small number; there is designer's demand for increasing the number of solid colors that can be used. Further, to prepare solid color ink, basic inks of about 20 colors need to be mixed in accordance with the mixing ratio defined in the color sample. When solid color ink is replaced, ink mixing work, printer cleaning work, and the like are required and thus solid color print involves a large number of steps at the print site; this is a problem.

To solve such a problem, in print technique, a color reproduction method called HiFi color print is proposed for the purpose of enlarging color gamut by perform color reproduction using five to seven colors in which at least one color of RGB is added to four process colors of YMCK, and making it possible to reproduce solid color colorimetrically by performing color separation processing. As HiFi color print, hexachrome print of Pantone is widely used; it is known that about 90% of solid color can be reproduced by performing color reproduction in six colors of four colors of YMCK plus R-based orange (O) ink and G ink. The color reproduction method of the HiFi color print, which will be hereinafter referred to as HiFi color, is general as a technique of enlarging the color gamut since the application range of HiFi color is also widened

to ink jet and electrophotographic color printers.

Further, in print and a color printer, a color signal of a display or a digital camera of sRGB color space, etc., may be input as an input signal. Since the color gamut of YMCK four-color process print or a color printer is narrower than the color gamut of the sRGB color space, there is demand for enlarging the color gamut intended for faithful reproduction. Also in such a case, enlarging the color gamut using the HiFi color is effective.

Thus, in the HiFi color, it is possible to enlarge the color gamut of a color printer. At this time, to well reproduce a colorimetric value signal of input solid color and an sRGB color signal, it is necessary to match the tristimulus values of print of output matter with the tristimulus values of the input color signal, namely, realize colorimetric color reproduction in color conversion processing of converting the input color signal into a an image record signal of five to seven colors.

A color management system (CMS) based on the specifications proposed by International Color Consortium (ICC) widely prevalent as industrial standard at present converts an RGB color signal of an input color signal of machine-dependent color space into a device-independent color signal like L*a*b* or XYZ color space and then converts the device-independent color signal into a YMCK color signal of

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a color printer of machine-dependent color space. As such conversion processing is performed, the input color signal and the output image record signal match in device-independent color signal and thus it is possible to ensure colorimetric color

5   reproduction. As the CMS, ColorSync installed in the Mac (registered trademark) operating system of Apple and ICM installed in Windows (registered trademark) of Microsoft are representative.

It is also considered in the HiFi color that a CMS in

10   conformity with ICC is adopted for realizing colorimetric color reproduction. To do this, color conversion from a device-independent color signal like L*a*b* or XYZ color space to an image record signal of five to seven colors may be realized. The following technique is proposed as a related art of color

15   conversion processing for the HiFi color:

U.S. Patent No.4,812,899 discloses an image formation apparatus for performing color reproduction in process inks of seven colors of YMCKRGB. In the image formation apparatus, color conversion from an RGB signal of an input machine such

20   as a scanner to YMCKRGB of an output machine such as a printer is determined by UCR (Under Color Removal) of achromatic component and chromatic component, and a technique called Kueppers Technique is proposed. This technique is the first proposed technique as color conversion processing of the HiFi

25   color and has an easy algorithm and thus is widely utilized.

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Considering application of Kueppers Technique to color conversion in conformity with ICC, it is possible to adopt a method of converting a device-independent color signal like L*a*b* color space into an RGB color signal by any color conversion unit and performing UCR processing of achromatic component and chromatic component for the RGB signal. However, as with the usual UCR processing, a colorimetric match between the RGB color signal of an input color signal and the YMCKRGB color signal of an image record signal is not considered and therefore the technique cannot realize colorimetric color reproduction and color conversion accuracy is poor; this is a problem. Further, as with the usual UCR processing, the technique involves a problem of incapability of making full use of the color gamut of an output machine and a problem of incapability of making full use of the color gamut widened in the HiFi color.

In contrast, the following technique called a division method is proposed: The color gamut of the HiFi color consisting of five to seven colors is divided into color gamut divisions each involving three or four colors in combination, and color conversion from the colorimetric value is performed in each color gamut division according to a similar technique to that with a usual three-color or four-color printer. For example, JP-A-2000-32284 proposes a technique of using color gamut divisions each involving K and other two colors close to K in

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hue in combination and determining coefficients in a direct look-up table (DLUT) for color conversion processing for realizing colorimetric color reproduction. For example, JP-A-2001-136401 proposes a technique of using color gamut divisions each involving K and other three colors in combination and determining DLUT coefficients for color conversion processing for realizing colorimetric color reproduction. Further, for example, U.S. Patent No.5,563,724 proposes a method of forming k (k<n) color gamut divisions each consisting of m color inks in an image formation apparatus of n (n>4) color inks and creating a printer model for each color gamut division, thereby converting from CIE color space into n-color inks color space so that a colorimetric match is found in the color gamut division and the color difference becomes the minimum outside the color gamut division. Further, for example, U.S. Patent No.5,892,891 describes a color conversion method from the colorimetric value in five-colors process of YMCKO; it proposes a method of executing color conversion of the colors in the YMCK color gamut from a colorimetric value. A color in the YMCK color gamut is converted from L*a*b* color space to YMCK. A color outside the YMCK color gamut is color-converted using a color gamut division to which a solid color is added (YOMK color gamut).

Each of the division methods disclosed in the documents has the advantage that the color conversion accuracy is high

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because colorimetric color reproduction in each color gamut division is insured. Although the computation amount is large as compared with Kueppers Technique, the division method is rarely used directly to perform color conversion; usually, it

5   is used only for determining the lattice point parameter of DLUT for executing color conversion from L*a*b* color space to color signal of five to seven colors of an output machine, and therefore the large computation amount does not introduce any problem.

10   Thus, the division method has the advantage that the color conversion accuracy is high because colorimetric color reproduction is insured. However, the division method involves an intrinsic problem such that the color separation values become discontinuous on the boundary between the color gamut divisions

15   and a pseudo contour occurs, as described in JP-A-2001-136401. Then, in the method disclosed in JP-A-2001-136401, occurrence of pseudo contours is suppressed by performing smoothing processing of the lattice point parameters of DLUT determined by the division method. However, a new problem is caused, that

20   is, the smoothing processing worsens the color conversion accuracy. That is, in the division method, prevention of a pseudo contour and realizing high color conversion accuracy cannot be made compatible; this is a problem of the division method.

25   Further, a problem occurs in addition to occurrence of

the pseudo contour in the boundary depending on the division method into color gamut divisions. In the color gamut division methods disclosed in JP-A-2000-32284 and U.S. Patent No.5,563,724, each color gamut division is made up of two or

5 three adjacent colors containing K. In the division methods, the gray axis becomes a single color of K and thus gray cannot be reproduced in three colors of YMC; this is a problem. Usually, gray reproduced in the K single color is poorer in graininess than gray reproduced in the three colors of YMC and therefore

10 a problem of poor graininess in the proximity of the gray axis occurs in the division method. In the division method, the place where the maximum density is generated becomes a K signal color solid part and the maximum density is lower than that in a YMCK four-color solid part in the YMCK four-color process.

15 Full use of the color gamut in the high-density part that should be able to be reproduced essentially cannot be made; this is a problem.

In contrast, in the methods disclosed in JP-A-2001-136401 and U.S. Patent No.5,892,891, one of the color gamut divisions

20 is formed of the YMCK color gamut, whereby gray can be reproduced in three colors of YMC and the place where the maximum density is generated can be made a YMCK four-color solid part, so that the graininess in the proximity of the gray axis can be improved and full use of the color gamut of the high-density part can

25 be made. However, in the method, discontinuousness of the color

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separation values in the boundary between color gamut divisions containing RGB and the YMCK color gamut is very large as compared with that in the division methods disclosed in JP-A-2000-32284 and U.S. Patent No.5,563,724. There is a problem of easy occurrence of a pseudo contour.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a color image processing method and apparatus for making it possible not only to insure the colorimetric color reproduction but also to provide smooth gradation representation with no occurrence of any pseudo contour as caused by the division method of the related art for insuring colorimetric color reproduction, as a color conversion processing for HiFi color. In addition, it is another object of the invention to provide a color image processing method and apparatus for making it possible to control the black amount and the solid color amount as desired with considering the image quality of graininess, etc., and further making it possible to make full use of the color gamut in a high-density part.

According to a first aspect of the invention, a color image processing method converts a first color signal including three variables into a second color signal including N variables, where N is an integer, which is not smaller than four. The color image processing method includes a first conversion of

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determining (N-3) variables of the second color signal from the first color signal, and a second conversion of determining the remaining three variables of the second color signal on the basis of the determined (N-3) variables of the second color

5   signal and the first color signal so that the second color signal is colorimetrically equal to the first color signal. Particularly, the second conversion may include solving a function of the second color signal, which indicates a relation between the second color signal and a device-independent color

10   signal on color system coordinates corresponding to the second color signal, with using the first color signal and the determined (N-3) variables of the second color signal as an input. According to this configuration, colorimetric color reproduction is ensured. Since the function is formed without

15   dividing the color gamut, the color separation results are continuous and smooth gradation representation with no occurrence of any pseudo contour is made possible.

The N variables of the second color signal may include four variables indicating yellow, magenta, cyan, and black,

20   and at least one of three variables indicating red, green, and blue. Accordingly, a color conversion processing of HiFi color can be realized.

The (N-3) variables of the second color signal determined in the first conversion may include a variable indicating black,

25   at least two of four variables indicating red, green, and blue.

The three variables determined in the second conversion may include three variables indicating yellow, magenta, and cyan. Accordingly, it is made possible to control the black amount (K) and the solid color amount (RGB) as desired considering

5   the image quality of graininess, etc.

Further, the first conversion may include determining a UCR ratio concerning the (N-3) variables of the second color signal on the basis of the first color signal, determining maximum and minimum values of each of (N-3) variables of the

10   second color signal, which is inputtable in a color gamut, on the basis of the first color signal, and determining the (N-3) variables of the second color signal to be between the maximum and minimum values on the basis of the UCR ratio concerning the (N-3) variables of the second color signal and the maximum

15   and minimum values. Accordingly, it is made possible to control the black amount and the solid color amount as desired and it is also made possible to make full use of the color gamut.

Further, the first conversion may include determining a UCR ratio concerning an achromatic component, a UCR ratio

20   concerning a chromatic component, and three primary color signals, which represent the first color signal, on the basis of the first color signal, and performing a UCR processing on the basis of the achromatic component and a UCR ration concerning a chromatic ration to eliminate the achromatic component and

25   the chromatic component from the three primary color signals,

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to thereby determine the (N-3) variables of the second color signal. Accordingly, it is made possible to control the black amount and the solid color amount as desired and it is also made possible to determine the black amount and the solid color amount at high speed by the UCR processing. The three primary color signals may indicate yellow, magenta, and cyan.

The first color signal may be an L*a*b* color signal. Accordingly, colorimetric color reproduction match can be realized.

According to the configuration of the invention, it is made possible to provide the color image processing method and apparatus for making it possible to perform smooth gradation representation with no occurrence of any pseudo contour of a problem in the division method to ensure colorimetric color reproduction in the related art as well as to ensure colorimetric color reproduction required as color conversion processing for HiFi color. In addition, it is made possible to provide the color image processing method and apparatus for making it possible to control the black amount and the solid color amount as desired considering the image quality of graininess, etc., and further making it possible to make full use of the color gamut in a high-density part.

Further, a second color signal is found for each of a plurality of first color signals using the color image processing method as described above, and a color conversion unit for using

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pairs of the first color signals and the second color signal to convert any first color signal into the second color signal can be provided. Particularly, as the color conversion unit, a direct look-up table of three inputs and N outputs can be used. Accordingly, the color conversion processing can be executed at high speed and in addition, conversion processing with high color conversion accuracy can be realized.

The color image processing method as described above can also be formed as a color image processing program executed by a computer. The color image processing program can also stored on a storage medium.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram to show an example of a color DTP system using a color image processing apparatus of the invention.

FIG. 2 is a block diagram to show a first embodiment of color conversion section.

FIG. 3 is a schematic representation of an example of a list of the color difference evaluation results used in a black amount/solid color amount determination section.

FIG. 4 is a block diagram to show a second embodiment of color conversion section.

FIG. 5 is a flowchart to show an example of color conversion parameter determination processing of a three-dimensional DLUT

color conversion section 34 in the second embodiment of color conversion section.

FIG. 6 is a block diagram to show a third embodiment of color conversion section.

FIG. 7 is a schematic representation of an example of a computer program for realizing the function of the color image processing apparatus of the invention or the color image processing method of the invention and storage media storing the computer program.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a block diagram to show an example of a color DTP system using a color image processing apparatus according to a first embodiment of the invention. In the figure, numeral 11 denotes an original edit apparatus, numeral 12 denotes an image processing apparatus, numeral 13 denotes an image output unit, numeral 21 denotes an edit apparatus communication section, numeral 22 denotes a format conversion section, numeral 23 denotes a rasterizing section, numeral 24 denotes a color conversion section, and numeral 25 denotes an output unit communication section. To begin with, a color DTP system is taken as an example of a system incorporating the color image processing apparatus according to the first embodiment of the invention, and a configuration example of the color DTP system will be discussed.

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The color DTP system shown in FIG. 1 includes the original edit apparatus 11, the image processing apparatus 12, and the image output unit 13. The original edit apparatus 11 is an apparatus for preparing an electronic print original, and

5 outputs electronic original data in a page description language or raster image data to the image processing apparatus 12. Specifically, as the original edit apparatus 11, an original may be edited using various DTP applications in a general-purpose computer such as a personal computer or may be edited using

10 a dedicated computer.

To use a general-purpose computer, an electronic original is edited using various DTP software products. The prepared electronic original is converted into PostScript (registered trademark) of a page description language by PostScript

15 (registered trademark) printer driver of Adobe, for example, and the conversion result is output to the image processing apparatus 12 through a network such as Ethernet (registered trademark). It is apparent that the page description language to send the electronic original from the DTP personal computer

20 to the image processing apparatus 12 is not limited to PostScript (registered trademark) and may be any page description language.

To use a dedicated computer, an electronic original can be edited using a dedicated workstation called Color Electric Prepress System (CEPS) and an application. The prepared

25 electronic original is output to the image processing apparatus

12 through a network such as Ethernet (registered trademark) in the raster information format such as TIFF/IT format of standard of raster image data or Scitex format widely prevalent as print electronic data, for example. Of course, it is apparent that the raster information sent from CEPS to the image processing apparatus 12 is not limited to TIFF/IT and any image format may be used if the image data is in the raster format.

As color signal in an electronic original, it is a common practice to assume a printer as an output machine in color DTP and the color of the electronic original is specified using YMCK color signal of yellow, magenta, cyan, and black. In recent years, a print technology using five or more color inks called HiFi color print intended for improving the image quality with enhancement of color reproducibility has been available. In this case, usually an electronic original is represented using color signal of five to seven colors with one to three colors of red, green, and blue added as solid color. For the solid color, the colorimetric value is defined for each color sample in DTP software and the manufacturer of Pantone, etc., and the color sample number are specified on the electronic original, whereby the color is specified with the colorimetric value of L*a*b* color signal, etc. Further, recently, with the widespread use of digital cameras and standardization of color reproduction of RGB color signal such as sRGB color space, it has been also a common practice to specify the color using RGB

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color signal in color DTP. It is assumed that the color DTP system in the example is that used at the print site, but the invention is not limited to it and the color DTP system may a color DTP system used in an office or a home. For example,

5 in an office, the color space of a display is used as the color signal on an electronic original, and the sRGB color space is generally used.

The image processing apparatus 12 includes the edit apparatus communication section 21, the format conversion

10 section 22, the rasterizing section 23, the color conversion section 24, and the output unit communication section 25. The image processing apparatus 12 converts an electronic original of code information or raster information input from the original edit apparatus 11 into an outputtable format in the image output

15 unit 13 and outputs the conversion result to the image output unit 13.

The electronic original specified in color signal of YMCK, YMCKRGB, RGB, L*a*b*, etc., transmitted from the original edit apparatus 11 is received by the edit apparatus communication

20 section 21 through a network such as a LAN and is transferred to the format conversion section 22 and the rasterizing section 23. The page description language is converted by the rasterizing section 23 into image data in the raster format of an outputtable format in the image output unit 13 and at

25 the same time, the image data undergoes color conversion

processing and is converted into L*a*b* color signal of device-independent color space. Image data in the raster format such as TIFF/IT is subjected to resolution conversion and format conversion processing in the format conversion section 22 and is converted into image data in the raster format of an outputtable format in the image output unit 13 and at the same time, the image data undergoes color conversion processing and is converted into L*a*b* color signal of device-independent color space.

The L*a*b* color signal transferred from the rasterizing section 23 and the format conversion section 22 is converted by the color conversion section 24 into an image record signal having variables of five or more colors including yellow, magenta, cyan, black, and one or more solid colors, of color space of the image output unit 13. In the description that follows, orange is assumed as a specific example of the solid color and it is assumed that the color signal is converted into an image record signal of five colors of YMCKO using orange as well as yellow, magenta, cyan, and black. Of course, the solid color to be used is not limited to orange.

The image record signal provided by the color conversion section 24 is transferred to the output unit communication section 25. The output unit communication section 25 stores the image record signal subjected to the processing by the format conversion section 22 to the color conversion section 24 and

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transfers the image record signal to the image output unit 13 at a appropriate timing, thereby absorbing the processing speed difference between the image processing apparatus 12 and the image output unit 13. In the image output unit 13, an image

5   is formed on paper in accordance with the image record signal in the raster format of five colors of YMCKO.

Color conversion processing from YMCK, YMCKRGB, or RGB color signal into L*a*b* color signal in the rasterizing section 23 and the format conversion section 22 can be realized by CMS

10 in compliance with the known ICC specifications. If the input signal is L*a*b* color signal, the color conversion processing may be skipped. Further, in the example, the color signal input to the color conversion section 24 is not limited to the L*a*b* color signal. The color conversion section 24 may be configured

15 so that the input signal is in device-independent color space on the color system coordinates of XYZ, etc. It is apparent that even among the RGB color space, which is a device-dependent color space, a color space, for which conversion into the colorimetric value is defined, such as the sRGB color space

20 may be used.

The image output unit 13 may be any if it records an image in the color signal of five or more colors. Any image output unit may be used so long as it is an electrophotographic color printer or an ink jet, thermal transfer, or sliver-salt photo

25 color image output unit, for example.

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Next, the color conversion section 24 of a component for implementing the color image processing apparatus according to the first embodiment of the invention or a color image processing method according to the first embodiment of the invention will be discussed. FIG. 2 is a block diagram to show the color conversion section of the first embodiment. In the figure, numeral 31 denotes a black amount/solid color amount determination section, numeral 32 denotes a YMC determination section, and numeral 33 denotes an image record signal output section. The L*a*b* color signal transferred from the rasterizing section 23 and the format conversion section 22 to the color conversion section 24 is input to the black amount/solid color amount determination section 31 and the YMC determination section 32. The black amount/solid color amount determination section 31 determines black amount K and solid color amount O from the input L*a*b* color signal and transfers K and O to the YMC determination section 32 and the image record signal output section 33. The YMC determination section 32 determines the YMC color signal of the image output unit 13 colorimetrically matching the L*a*b* color signal input under the condition that the black amount is K color signal and the solid color amount is O color signal from the L*a*b* color signal input from the rasterizing section 23 and the format conversion section 22 on the basis of the KO color signal input from the black amount/solid color amount determination section 31, and

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transfers the YMC color signal to the image record signal output

section 33. The image record signal output section 33 transfers

the KO color signal input from the black amount/solid color

amount determination section 31 and the YMC color signal input

5   from the YMC determination section 32 to the output unit

communication section 25. The color conversion processing of

the color conversion section 24 is now complete.

The black amount/solid color amount determination section

31 determines the black amount K and the solid color amount

10   O from the input L*a*b* color signal. To do this, the

relationship between the image record signal YMCKO of the image

output unit 13 and the colorimetric value L*a*b* at that time

is previously found as a function, which will be hereinafter

referred to as color conversion model. The color conversion

15   model is numerically solved with the L*a*b* color signal obtained

from the rasterizing section 23 and the format conversion section

22 and a combination of the black amount K and the solid color

amount O as input, thereby calculating the YMC color signal

of the remaining three colors of the image output unit 13

20   colorimetrically matching the L*a*b* color signal. Next, the

color difference between a colorimetric value, which is

reproduced by a combination of the black amount K and the solid

color amount O and the provided YMC color signal, and the input

color signal L*a*b* is determined. Thereby, combinations of

25   the black amount K and the solid color amount O for making color

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reproduction possible in the color gamut of the image output unit 13 and combinations the black amount K and the solid color amount O for making color reproduction impossible are recorded in a list. The minimum value and the maximum value of the black

5 amount that can be input with respect to the input L*a*b* color signal, which will be hereinafter referred to as the minimum black amount and the maximum black amount, are determined from the list. The achromatic UCR ratio to the input L*a*b* color signal is determined based on a predetermined black input

10 function. The black amount K is determined from the maximum black amount, the minimum black amount, and the achromatic UCR ratio. Last, the minimum value and the maximum value of the solid color amount that can be input with respect to the input L*a*b* color signal, which will be hereinafter referred to as

15 the minimum solid color amount and the maximum solid color amount, are determined from the list. The chromatic UCR ratio with respect to the input L*a*b* color signal is determined based on a predetermined solid color input function. The solid color amount O is determined from the maximum solid color amount,

20 the minimum solid color amount, and the chromatic UCR ratio. It is noted that the term "UCR" represents "under control removable".

The YMC determination section 32 numerically solves the above-described color conversion model based on the L*a*b* color

25 signal obtained from the rasterizing section 23 and the format

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conversion section 22 and the KO color signals obtained from the black amount/solid color amount determination section 31, thereby determining the YMC color signal of the remaining three colors of the image output unit 13, which colorimetrically

5   matching the input L*a*b* color signal and has the black amount of the image output unit 13 being K color signal and the solid color amount being O color signal.

The image record signal output section 33 transfers the image record signal YMCKO to be input to the image output unit

10   13 to the output unit communication section 25.

Next, the processing of the sections will be discussed specifically. To begin with, the preparation method of the color conversion model of the image output unit 13 will be discussed. The image output unit 13 prints out color patches

15   for any desired combination of image record signal YMCKO of the image output unit 13. The colorimetric values L*a*b* of the color patches are measured using a colorimeter.

For example, as a combination of image record signals YMCKO, a set of $6 \times 6 \times 6 \times 6 \times 6 = 7,776$ patches with dot values

20   of each color in 20% steps is printed out by the image output unit 13, and color measurement is conducted. To do this, for example, X-Rite938 of a colorimeter manufactured by X-Rite can be used as a colorimeter and L*a*b* can be measured under the measurement conditions of D50 and 2-degree field of view. Any

25   number of color patches used for color measurement can be used;

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however, it is desirable that a large number of patches as much as possible should be used for providing high accuracy of the color conversion model. As a color system used for color measurement, here L*a*b* color system of uniform color space is used, but any other color system such as XYZ color system may be used. However, to evaluate the color difference when the color conversion model is solved, it is preferable that the uniform color space is used.

Next, a neural network is made to learn a plurality of YMCKO and L*a*b* data sets obtained as teacher data. Here, the relationship between YMCKO and L*a*b* can be represented by the following function:

$$(L*, a*, b*) = F (Y, M, C, K, O) \qquad (1)$$

Expression (1) is dissolved into color components as follows:

$$L* = FL (Y, M, C, K, O) \qquad (2)$$

$$a* = Fa (Y, M, C, K, O) \qquad (3)$$

$$b* = Fb (Y, M, C, K, O) \qquad (4)$$

The neural network used as the color conversion model may be, for example, a neural network disclosed in a document "An accurate color transformation algorithm based on flexible GCR - (2) accurate printer model by neural network", Kazumasa MURAI et al., Japan Hard Copy '94 Collected Papers, pp. 181-184, and back propagation method can be used for learning. The image record signal in this document is four colors of YMCK. However, the number of cells in the first layer in the neural network

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is increased from four to five, whereby the image record signal can be used as the color conversion model for HiFi color of five colors. Of course, as the color conversion model, any other polynomial model or a color conversion model in a

5   conversion table form can also be applied in addition to use of the neural network.

Next, the numerical solution method of the color conversion model will be discussed. Here, inverse function of function F cannot uniquely be found. However, if L*a*b*

10   is given and two variables of YMCKO are determined appropriately, the remaining three variables can be found from expression (1). For example, if K and O are given, YMC can be determined. Here, it is assumed that the color to be reproduced is L*a*b* and that the given black amount and solid color amount are K and

15   O. In this case, a color difference ΔE*ab between a color to be reproduced and a color reproduced from the image record signal YMC, the black amount K, and the solid color amount O is defined by the following expression as a function of the image record signal YMC:

20   ΔE*ab(Y,M,C)

$$= ((L^* - FL(Y,M,C,K,O))^2 + (a^* - Fa(Y,M,C,K,O))^2$$
$$+ (b^* - Fb(Y,M,C,K,O))^2)^{1/2} \tag{5}$$

Solving expression (1) of a nonlinear equation is equivalent to finding the value of YMC, which makes the color

25   difference ΔE*ab be zero. When ΔE*ab is set as an objective

function, the problem of finding expression (1) can be interpreted as a nonlinear optimization problem of finding YMC for minimizing the objective function ΔE^*ab. Therefore, expression (1) can be solved according to a nonlinear

5 optimization technique such as a simplex method. As for the simplex method, simplex algorithm is introduced in "Nonlinear Programming" Hiroshi Konno, Nichikagiren shuppansha, pp. 284-287, for example. The simplex method is a technique fitted for optimization of such a multi-variable function, and the

10 optimum value can be found at high speed. Of course, not only the simplex method, but also any nonlinear optimization technique may be applied; any other nonlinear optimization technique such as dichotomy or golden section search may be applied. A numeric solution method of a nonlinear equation

15 such as Newton's method may be applied for solving the color conversion model.

As the color conversion model is thus solved, the YMC color signal of the remaining three colors of the image output unit 13, which colorimetrically matches the input L*a*b* color

20 signal and has the black amount of the image output unit 13 being K color signal and the solid color amount being O color signal, can be determined on the basis of the L*a*b* color signal, the black amount K, and the solid color amount O. Since the above-described color conversion model is formed without

25 dividing the color gamut of the image output unit 13,

26

discontinuousness of the color separation result in the boundary

between the color gamut divisions causing a problem in the

division method of the related art does not occur on a principle

and smooth gradation representation with no pseudo contours

5   is made possible.

Next, the determination method of the black amount K and

the solid color amount O in the black amount/solid color amount

determination section 31 will be discussed. If L*a*b* is given

to expression (1) of the color conversion model and two variables

10   of YMCKO are determined appropriately, the remaining three

variables can be found according to the numeric solution method,

as described above. That is, if the black amount K and the

solid color amount O are determined with respect to the input

L*a*b* color signal, the remaining YMC can be determined. Here,

15   the expression (5) of the objective function used for solving

expression (1) of the color conversion model represents the

color difference between the L*a*b* color signal of the input

color signal and the color reproduced from the YMCKO signal

determined in the image output unit 13. If the color difference

20   is zero, this represents that the input color signal is in the

color gamut of the image output unit 13. If the color difference

is greater than zero, this represents that the input color signal

is outside the color gamut of the image output unit 13. Therefore,

when the color difference of expression (5) of the objective

25   function is determined for a preset combination of the black

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amount K and the solid color amount O, whether the combination of the black amount K and the solid color amount O makes color reproduction possible or impossible in the color gamut of the image output unit 13 can be determined. In order to determine

5   the black amount K and the solid color amount O while insuring colorimetric color reproduction and making it possible to use the most of the color gamut of the image output unit 13, the range of the black amount K and the solid color amount O for making color reproduction possible in the color gamut may be

10   found and the black amount K and the solid color amount O may be set within the range.

Here, color signal of the image output unit usually is quantized about 256 steps of gradation. Therefore, even if all combinations of the black amount K and the solid color amount

15   O are calculated, the determination method of the range of the black amount K and the solid color amount O for making color reproduction possible in the color gamut considers 256 × 256 = 65536 color differences using expression (5). FIG. 3 is a schematic representation of an example of a list of the color

20   difference evaluation results used in the black amount/solid color amount determination section 31. For simplicity, FIG. 3 shows the evaluation results of color difference $\Delta E^*a^*b^*$ for all combinations of the black amount K and the solid color amount O when the black amount K and the solid color amount O are 0,

25   25, 50, 75, 100 with respect to the input $L^*a^*b^*$ color signal.

In the list of FIG. 3, when the combination of the black amount K and the solid color amount O is in the color gamut, a circle is entered as the evaluation result; when the combination is outside the color gamut, × is entered.

5   Next, the range of the black amount K and the solid color amount O for making color reproduction possible in the color gamut is determined from the list of FIG. 3. Here, the order of the colors to be determined needs to be determined. Since the black amount K has a large effect on the image quality,

10   first the black amount K is determined and a case where the combination of the black amount K and the solid color amount O makes color reproduction possible in the color gamut is deemed as the range of the black amount K for making color reproduction possible. Then, it is determined that the minimum black amount

15   in the color gamut (minK) is 0% and that the maximum black amount (maxK) is 75%. Here, assuming that the minimum black amount is not found and is the case where black is not added, minK may be set to 0. Here, setting achromatic UCR ratio = α, the black amount K may be determined between the minimum and maximum

20   black amounts and therefore can be determined according to the following expression:

$$K = \text{mink} + (\text{maxK} - \text{minK}) \times \alpha \qquad (6)$$

For example, letting the achromatic UCR ratio α be 33.3%, the black amount K in the list of FIG. 3 is determined 25% from

25   expression (6). In addition to the method of thus giving the

achromatic UCR ratio α at a fixed rate, the achromatic UCR ratio α may be defined as a function of lightness or chroma saturation because graininess worsens if black is mixed into a high-lightness part or a high-chroma part. That is, the achromatic UCR ratio may be determined according to the black input function with the L*a*b* color signal of an input color signal as input.

For example, when the black amount K is determined 25%, the column with K=25 in the list of FIG. 3 is referenced and a search is made for the minimum and maximum values of the solid color amount with the color difference becoming zero, whereby it is determined that the minimum solid color amount in the color gamut (minO) is 0% and that the maximum solid color amount (maxO) is 50%. Here, assuming that the minimum solid color amount is not found and is the case where no solid color is added, minO may be set to 0. Here, setting chromatic UCR ratio = β, the solid color amount O may be determined between the minimum and maximum solid color amounts and therefore can be determined according to the following expression:

$$O = minO + (maxO - minO) \times \beta \qquad (7)$$

Here, letting the chromatic UCR ratio β be 100%, the solid color amount O in the list of FIG. 3 is determined 50% from expression (7). In addition to the method of thus giving the chromatic UCR ratio β at a fixed rate, the chromatic UCR ratio β may be defined as a function of lightness or chroma saturation like

the achromatic UCR ratio. That is, the chromatic UCR ratio may be determined according to the solid color input function with the L*a*b* color signal of an input color signal as input.

In the example of the list of FIG. 3, the minimum and maximum black amounts and the minimum and maximum solid color amounts can be found, but may be unable to be found because the input color signal L*a*b* is outside the color gamut. In such a case, the combination of the black amount K and the solid color amount O corresponding to the minimum color difference in the list may be determined as the black amount K and the solid color amount O.

In the example, the black amount K is first determined and the solid color amount O is next determined, but the determining order is not limited to this; the solid color amount O may be first determined and the black amount K may be next determined. Of course, this also applies if any other solid color is used.

In the example, the range of the black amount K and the solid color amount O for making color reproduction possible is calculated by evaluating the color difference for all combinations of the black amount K and the solid color amount O. However, the determination method of the range for making color reproduction possible is not limited to this; maxK, minK, maxO, and minO may be found by any other method such as binary search algorithm.

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Further, in the description given above, the black amount K and the solid color amount O are first determined and then the remaining YMC color signal to ensure colorimetric color reproduction is determined. However, the color signal to be first determined is not limited to the black amount K or the solid color amount O. To determine the color signal of five colors as described above, two colors may be first determined in such a manner that the Y color signal and the M color signal are first determined and then the black amount K, the solid color amount O, and the C color signal are determined, for example. With regard to the number of color signals passed to the image output unit 13, HiFi color of five colors with four process colors of YMCK to which one solid color, orange, is added is shown as an example. However, the solid color is not limited to orange and the number of solid colors is not limited to one either. Color conversion processing can also be performed by a similar method for six colors with orange and green added to the four colors of YMCK or seven colors with red, green, and blue added to the four colors of YMCK, for example.

The YMC determination section 32 can also numerically solve the color conversion model by the above-described method, thereby determining the YMC color signal of the remaining three colors of the image output unit 13, which colorimetrically matches the input $L^*a^*b^*$ color signal and has the black amount of the image output unit 13 being K and the solid color amount

being O, on the basis of the L*a*b* color signal obtained from the rasterizing section 23 and the format conversion section 22 and the black amount K and the solid color amount O obtained from the black amount/solid color amount determination section

5   31. Since the YMCKO color signal is thus determined, it is possible to ensure colorimetric color reproduction. Since the used color conversion model is formed without dividing the color gamut of the image output unit 13, a pseudo contour of the problem in the division method of the related art does not occur.

10   Thus, the black amount K and the solid color amount O of the image output unit 13 are determined from the L*a*b* color signal of an input color signal on the basis of the range of the black amount K and the solid color amount O for making color reproduction possible in the color gamut found by solving the

15 color conversion model of the image output unit 13 using the numerical solution method and the achromatic UCR ratio and the chromatic UCR ratio determined from the L*a*b* color signal. Accordingly, the black amount and the solid color amount can be controlled as desired with respect to the L*a*b* color signal

20 of the input color signal considering the image quality of graininess, etc., and it is made possible to make full use of the color gamut of the image output unit. Further, as described above, the remaining three-variable color signal YMC of the image output unit 13 is determined from the black amount K,

25 the solid color amount O, and the input color signal L*a*b*

by solving the color conversion model of the image output unit 13 using the numerical solution method so that the YMC color signal becomes colorimetrically equal to L*a*b* of device-independent color signal, whereby it is made possible

5   to ensure colorimetric color reproduction. Particularly, occurrence of a pseudo contour is a problem in the division method to ensure colorimetric color reproduction in the related art; in the invention, however, since the color conversion model of the image output unit 13 is formed without dividing the color

10   gamut, smooth gradation representation with no occurrence of any pseudo contour is made possible.

        FIG. 4 is a block diagram to show a color conversion section according to a second embodiment. In the figure, numeral 34 denotes a three-dimensional DLUT color conversion section. In

15   color conversion section 24 of the second embodiment, the color conversion section 24 is implemented as the three-dimensional DLUT color conversion section 34 having three inputs and five outputs.

        The three-dimensional DLUT color conversion section 34

20   is implemented as a three-dimensional direct look-up table (DLUT) for inputting L*a*b* color signal and outputting YMCKO color signal corresponding to the L*a*b* color signal. For example, it is a three-dimensional DLUT for using the value resulting from dividing each axis of the input L*a*b* color

25   signal by 16 as input address, performing interpolation

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operation by cubic interpolation, and calculating image record

signal YMCKO of the image output unit 13. Of course, the

interpolation is not limited to the cubic interpolation and

any other interpolation such as triquetrous interpolation or

5   tetrahedral interpolation may be applied if it is known

interpolation. It is also apparent that the number of divisions

of each axis of the input signal is not limited to 16.

Here, the color conversion section 24 is implemented as

the three-dimensional direct look-up table, but is not limited

10   to this example so long as three-input, five-output color

conversion can be executed; any other color conversion technique

may be applied so long as it is a known color conversion technique

of a neural network, etc. Further, the color signal input to

the color conversion section 24 is not limited to the L*a*b*

15   color signal and may be formed so as to become device-independent

color space on color system coordinates of XYZ, etc. Even among

the RGB color space, which is a device-dependent color space,

a color space, for which conversion into the colorimetric value

is defined, such as the sRGB color space may be used as the

20   input color signal of the color conversion section 24.

FIG. 5 is a flowchart to show an example of color conversion

parameter determination processing of the three-dimensional

DLUT color conversion section 34 in the color conversion section

of the second embodiment. This processing is almost similar

25   to the processing of the color conversion section 24 of the

35

first embodiment.

To begin with, at step S1, the image output unit 13 prints out color patches for any desired combination of image record signal YMCKO of the image output unit 13. Then, the colorimetric value L*a*b* at this time is measured using a colorimeter. The combination of the image record signal YMCKO and the color measurement conditions may be similar to those in the first embodiment described above.

At step S2, a neural network of color conversion model is made to learn a plurality of YMCKO and L*a*b* data sets obtained at step S1 as teacher data. The neural network may be similar to that used in the first embodiment described above.

At step S3, for combinations of the black amount K and the solid color amount O with respect to the input address value L*a*b* of the three-dimensional DLUT color conversion section 34, L*a*b*, K, and O are input to the neural network (color conversion model) and the neural network is solved by a numeric resolution method, whereby the combinations of the black amount K and the solid color amount O for making color reproduction possible in the color gamut and the combinations of the black amount K and the solid color amount O for making color reproduction impossible are recorded in a list. The numerical solution method of the neural network of the color conversion model, the calculation method of the list for determining the range of the black amount K and the solid color amount O, and

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the like may be similar to those in the first embodiment described above.

At step S4, the minimum and maximum black amounts with respect to the input address value L*a*b* of the three-dimensional DLUT color conversion section 34 are found according to the list provided at step S3. The determination method of the minimum and maximum black amounts may also be similar to that in the first embodiment described above.

At step S5, the achromatic UCR ratio to L*a*b* is found according to a predetermined black input function, and the black amount K is determined from the maximum and minimum black amounts and the achromatic UCR ratio. The black amount K can be determined, for example, using a similar method to that in the first embodiment using expression (6) shown in the first embodiment described above.

At step S6, the minimum and maximum solid color amounts are found according to the list provided at step S3 and the black amount K found at step S5. The determination method of the minimum and maximum solid color amounts may also be similar to that in the first embodiment described above.

At step S7, the chromatic UCR ratio to L*a*b* is found according to a predetermined solid color input function, and the solid color amount O is determined from the maximum and minimum solid color amounts and the chromatic UCR ratio. The solid color amount O can be determined, for example, using a

37

similar method to that in the first embodiment using expression (7) shown in the first embodiment described above.

At step S8, L*a*b*, the black amount K, and the solid color amount O are input to the neural network and the neural network is solved by a numeric resolution method, whereby the value of YMC colorimetrically matching is calculated. The numerical solution method of the neural network may be similar to that in the first embodiment described above.

Last, at step S9, the image record signal YMC obtained at step S8, the black amount K obtained at step S5, and the solid color amount O obtained at step S7 are set in the lattice points of the three-dimensional DLUT color conversion section 34, whereby the color conversion parameter of the three-dimensional DLUT color conversion section 34 can be determined.

The color conversion parameter of the three-dimensional DLUT color conversion section 34 is thus previously determined. For example, the values of YMCKO at the lattice points provided by dividing each axis of the input L*a*b* color signal by 16 are set in the three-dimensional DLUT color conversion section 34. The actually input L*a*b* color signal is not limited to the lattice point and any desired L*a*b* color signal is input. Therefore, to perform color conversion processing, one or more lattice point addresses are generated based on the input L*a*b* color signal, the value of YMCKO is read, and interpolation

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processing is performed, whereby the YMCKO color signal corresponding to the input L*a*b* color signal is obtained.

Thus, in the second embodiment, direct color conversion is executed with the previously prepared direct look-up table without performing processing involving a large amount of computation to perform color conversion processing in the color conversion section 24 as in the configuration shown in the first embodiment described above, so that it is made possible to accomplish color conversion at very high speed. If a hardware configuration is adopted, the configuration can be made simple because the computation amount is small.

Next, a third embodiment of color conversion section 24 will be discussed. In the third embodiment, color signal (black amount and solid color amount) of (N-3) variables of N variables is determined according to a different configuration from that in the first embodiment described above. In the third embodiment, as an image record signal of the image output unit 13, an image is output by HiFi color including seven colors of four process colors of YMCK and three colors of red R, green G, and blue B. Of course, in the third embodiment, the solid colors added to the four process colors of YMCK are not limited to RGB.

FIG. 6 is a block diagram to show a color conversion section of the third embodiment. In the figure, numeral 35 denotes a three primary color signal conversion section, numeral 36

denotes an achromatic UCR conversion section, numeral 37 denotes a chromatic UCR conversion section, numeral 38 denotes a YMC determination section, and numeral 39 denotes an image record signal output section. As shown in FIG. 6, in the color

5 conversion section 24 of the third embodiment, the three primary color signal conversion section 35, the achromatic UCR conversion section 36, and the chromatic UCR conversion section 37 are provided as components for determining the black amount and the solid color amount. The YMC determination section 38

10 for determining the remaining YMC color signal from the black amount K, the solid color amount RGB, and input color signal L*a*b* and the image record signal output section 39 for transferring an image record signal YMCKRGB to the output unit communication section 25 have the same functions as the YMC

15 determination section 32 and the image record signal output section 33 in the first embodiment described above although they differ in the number of solid colors.

The L*a*b* color signal transferred from the rasterizing section 23 and the format conversion section 22 to the color

20 conversion section 24 is input to the three primary color signal conversion section 35, the achromatic UCR conversion section 36, the chromatic UCR conversion section 37, and the YMC determination section 38. The three primary color signal conversion section 35 converts the input L*a*b* color signal

25 into Y'M'C' color signals, which are three primary colors of

complementary colors and transfers the Y'M'C' color signals to the achromatic UCR conversion section 36.

The achromatic UCR conversion section 36 determines a UCR ratio concerning the achromatic component according to a predetermined black input function from the L*a*b* color signal input from the rasterizing section 23 and the format conversion section 22, and determines the black amount K and Y"M"C" color signal by performing UCR processing from the Y'M'C' color signal input from the three primary color signal conversion section 35. Then, the achromatic UCR conversion section 36 transfers the determined Y"M"C" color signal to the chromatic UCR conversion section 37 and the determined black amount K to the YMC determination section 38 and the image record signal output section 39.

The chromatic UCR conversion section 37 determines a UCR ratio concerning the chromatic component according to a predetermined solid color input function from the L*a*b* color signal input from the rasterizing section 23 and the format conversion section 22. Then, the chromatic UCR conversion section 37 determines the solid color amount RGB by performing UCR processing using the determined UCR ratio from the Y"M"C" color signal input from the achromatic UCR conversion section 36 and transfers the determined solid color amount RGB to the YMC determination section 38 and the image record signal output section 39.

The YMC determination section 38 receives the L*a*b* color signal from the rasterizing section 23 and the format conversion section 22, the black amount K from the achromatic UCR conversion section 36, and the solid color amount RGB from the chromatic

5   UCR conversion section 37. Then, the YMC determination section 38 determines the YMC color signal, which is the remaining three variable color signals of the image record signal, colorimetrically matching the L*a*b* color signal of the input color signal on the basis of the received L*a*b* color signal,

10   black amount K, and solid color amount RGB, and transfers the determined YMC color signal to the image record signal output section 39.

The image record signal output section 39 transfers the black amount K input from the achromatic UCR conversion section

15   36, the solid color amount RGB input from the chromatic UCR conversion section 37, and the YMC color signal input from the YMC determination section 38 to the output unit communication section 25.

The color signal input to the color conversion section

20   24 is not limited to the L*a*b* color signal and may be device-independent color space on color system coordinates of XYZ, etc. Even among the RGB color space, which is a device-dependent color space, a color space, for which conversion into the colorimetric value is defined, such as the

25   sRGB color space may be used.

The processing of the sections will be discussed in more detail. The three primary color signal conversion section 35 converts the L*a*b* color signal obtained from the rasterizing section 23 and the format conversion section 22 into Y'M'C'

5   color signals, which are three primary colors of complementary colors. As three-input, three-output color conversion from the colorimetric value into the three primary colors, a known color conversion processing method typified by CMS based on the specifications proposed by ICC can be used. For example,

10   conversion from the L*a*b* color signal into the Y'M'C' color signal can be executed according to a three-dimensional direct look-up table.

In the example, the YMC color space of the image output unit 13 is used as the color space of the Y'M'C' color signal

15   output from the three primary color signal conversion section 35. However, any other YMC color space may be used considering the color conversion accuracy, full use of the color gamut, etc. Further, conversion into the RGB color space of three primary colors of primary color systems rather than conversion

20   into the YMC color space of three primary colors of complementary color systems may be performed.

The achromatic UCR conversion section 36 determines the UCR ratio concerning the achromatic component according to the predetermined black input function from the L*a*b* color signal

25   input from the rasterizing section 23 and the format conversion

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section 22, as described above. Then, the achromatic UCR conversion section 36 converts the Y'M'C' color signal obtained from the three primary color signal conversion section 35 into the black amount K and Y"M"C" color signal by performing UCR

5 processing using the determined UCR ratio. The UCR processing can be implemented by a known method. For example, the UCR processing concerning the achromatic component can be implemented by operations performed based on the following expressions (8) to (12):

10 $$\text{Kacro} = \min (Y',M',C') \qquad (8)$$

$$K = \text{UCRacro} (L^*,a^*,b^*) \times \text{Kacro} \qquad (9)$$

$$Y" = Y' - \text{Kacro} \qquad (10)$$

$$M" = M' - \text{Kacro} \qquad (11)$$

$$C" = C' - \text{Kacro} \qquad (12)$$

15 Kacro denotes the minimum value of the Y'M'C' color signal and represents the achromatic component of the Y'M'C' color signal. UCRacro (L^*,a^*,b^*) is a UCR function of the achromatic component and is a function of defining the UCR ratio of the achromatic component to the input $L^*a^*b^*$ color signal. For

20 example, to improve graininess by not mixing a black into a high-lightness part, it is advisable to set the UCR function of the achromatic component so that if L^* is 100 to 50, the UCR ratio is set to zero and that if L^* is 50 to 0, the UCR ratio changes linearly from 0% to 100%. The UCR ratio of the

25 achromatic component may also be fixed.

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The black amount K can be determined by multiplying the achromatic component Kacro by the UCR ratio of the achromatic component as shown in expression (9). The Y"M"C" color signal can be calculated by subtracting the achromatic component Kacro from the Y'M'C' color signal as shown in expressions (10) to (12).

The chromatic UCR conversion section 37 converts the Y"M"C" color signal obtained from the achromatic UCR conversion section 36 into the solid color amount RGB by performing UCR processing concerning the chromatic component. The UCR processing can be implemented by a known method. For example, the UCR processing can be implemented by operations performed based on the following expressions (13) and (14):

$$Scro = min \ (C1, C2) \hspace{3cm} (13)$$

$$S = UCRcro \ (L^*, a^*, b^*) \times Scro \hspace{2cm} (14)$$

One color of the Y"M"C" color signal becomes zero due to the URC processing of the achromatic component performed by the achromatic UCR conversion section 36, and C1 and C2 represent the color signals of two colors of the Y"M"C" color signal, which are not zero. Scro represents the chromatic component of the Y'M'C' color signal. UCRcro (L^*, a^*, b^*) is a UCR function of the chromatic component and is a function of defining the UCR ratio of the chromatic component to the input $L^*a^*b^*$ color signal. Here, the UCR ratio of the chromatic component is fixed to 100%. Of course, the UCR ratio of the

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chromatic component may be fixed to any percentage other than 100% or to enhance the UCR ratio in a high-chroma part, the UCR function may be used to set the UCR ratio of the chromatic component.

5   The solid color amount S is determined by multiplying the chromatic component Scro by the UCR ratio, as shown in expression (14). The solid color amount S becomes the color signal corresponding to R when C1 and C2 indicate Y"M"; the color signal corresponding to B when C1 and C2 indicate M"C";

10   the color signal corresponding to G when C1 and C2 indicate Y"C"; and the color signals of other two colors become zero.

       Thus, in the third embodiment, the black amount and the solid color amount are determined by performing UCR processing, whereby the black amount and the solid color amount can be

15   controlled as desired with respect to the input L*a*b* color signal considering the image quality of graininess, etc. In addition, the black amount and the solid color amount can be determined at extremely high speed as compared with the method shown as the first embodiment. However, in the first embodiment,

20   full use of the color gamut of the image output unit 13 can be made because the black amount and the solid color amount can be determined in the range of the black amount and the solid color amount for making color reproduction possible in the color gamut; whereas, in the third embodiment, the range of the black

25   amount and the solid color amount for making color reproduction

possible in the color gamut is not achieved. Therefore, it is expected that the black amount and the solid color amount may be too large or too small depending on the input color signal. When the black amount and the solid color amount are be too

5   large or too small, the input color signal that can be essentially reproduced in the color gamut may not be reproduced and that full use of the color gamut of the image output unit 13 may not be made. Therefore, to give a high priority to the processing speed even if the full use of the color gamut is a little sacrificed,

10   it is desirable that the configuration shown as the third embodiment should be used. To give a high priority to the full use of the color gamut rather than the processing speed, it is desirable that the configuration shown as the first embodiment should be used.

15   The YMC determination section 38 numerically solves the color conversion model of the image output unit 13 from the L*a*b* color signal received from the rasterizing section 23 and the format conversion section 22, the black amount K received from the achromatic UCR conversion section 36, and the solid

20   color amount RGB received from the chromatic UCR conversion section 37, thereby determining the YMC color signal of the remaining three colors of the image output unit 13, which colorimetrically match the input L*a*b* color signal and have the black amount of the image output unit 13 being K and the

25   solid color amount being RGB.

As for the color conversion model of the image output unit 13 and the numerical solution method, similar techniques to those in the first embodiment described above can be used. To prepare the color conversion model of the image output unit

5   13, the image output unit 13 prints out color patches for any desired combination of image record signal YMCKRGB of the image output unit 13. The colorimetric value L*a*b* at this time is measured using a colorimeter. As a combination of image record signal YMCKRGB, for example, a set of 4 x 4 x 4 x 4 x

10   4 x 4 x 4 = 16,384 patches with dot values of each color in 33.3% steps can be used. The image output unit 13 prints out such a patch set, and L*a*b* may be measured under similar color measurement conditions to those in the first embodiment.

A neural network is made to learn a plurality of YMCKRGB

15   and L*a*b* data sets thus obtained as teacher data. Here, the relationship between YMCKRGB and L*a*b* can be represented by the function shown in the following expression (15) as with the first embodiment:

$$(L^*, a^*, b^*) = F (Y, M, C, K, R, G, B) \tag{15}$$

20   Expression (15) is dissolved into color components as follows:

$$L^* = FL (Y, M, C, K, R, G, B) \tag{16}$$

$$a^* = Fa (Y, M, C, K, R, G, B) \tag{17}$$

$$b^* = Fb (Y, M, C, K, R, G, B) \tag{18}$$

In the document shown in the first embodiment, the number

25   of cells in the first layer in the neural network is increased

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from four to seven, whereby the image record signal can be used as the color conversion model for HiFi color of seven colors. Of course, as the color conversion model, any other polynomial model or a color conversion model in a conversion table form can also be applied in addition to use of the neural network.

The numerical solution method of the color conversion model can also be realized by a nonlinear optimization technique using color difference $\Delta E*ab$ between the color to be reproduced, $L*a*b*$, and the color when the image record signal YMC, the black amount K, and the solid color amount RGB are applied as objective function as with the first embodiment. As the nonlinear optimization technique, for example, a simplex method can be used as in the first embodiment. At this time, the objective function is given by the following expression:

$$\Delta E*ab \ (Y,M,C)$$
$$= ((L* - FL\ (Y,M,C,K,R,G,B))^2 + (a* - Fa\ (Y,M,C,K,R,G,B))^2$$
$$+ (b* - Fb\ (Y,M,C,K,R,G,B))^2)^{1/2} \qquad (19)$$

Since the color conversion model of the image output unit 13 is thus numerically solved, the YMC color signal of the remaining three colors of the image output unit 13 colorimetrically, which match the input $L*a*b*$ color signal and have the black amount of the image output unit 13 being K and the solid color amount being RGB, can be determined from the $L*a*b*$ color signal, the black amount K, and the solid color amount RGB. Accordingly, it is made possible to ensure

colorimetric color reproduction. Since the color conversion
model according to the embodiments of the invention is formed
without dividing the color gamut of the image output unit 13,
a pseudo contour of a problem in the division method of the

5 related art does not occur.

Last, the image record signal output section 39 transfers
the image record signal YMCKRGB to the output unit communication
section 25. The color conversion processing of the color
conversion section 24 is now complete.

10 In the description of the third embodiment, as the number
of color signals of the image output unit 13, HiFi color of
seven colors with four process colors of YMCK to which three
solid colors RGB are added is shown. However, the colors used
as the solid colors and the number of the solid colors are not

15 limited to them. Color conversion processing can also be
performed by a similar method for six colors with orange and
green added to the four colors of YMCK or five colors with orange
added to the four colors of YMCK, for example.

The color conversion parameter of a three-dimensional

20 direct look-up table with three inputs and seven outputs as
with the second embodiment may be determined in accordance with
the method described in the third embodiment to perform color
conversion processing. Accordingly, high-speed color
conversion processing can be accomplished.

25 Thus, in the color conversion section 24 of the third

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embodiment, from the L*a*b* color signal of the input color signal, the black amount K and the solid color amount RGB of the image output unit 13 are determined by performing the UCR processing of the achromatic component and the chromatic component. Accordingly, it is made possible to control the black amount and the solid color amount as desired with respect to the L*a*b* color signal of the input color signal considering the image quality of graininess, etc.. It is made possible to determine the black amount and the solid color amount at extremely high speed as compared with the first embodiment. The remaining three-variable color signal YMC of the image output unit 13 is determined from the black amount K and the solid color amount RGB determined as described above and the input color signal L*a*b* by solving the color conversion model of the image output unit 13 using the numerical solution method so that the YMC color signal becomes colorimetrically equal to L*a*b* of device-independent color signal, so that it is made possible to ensure colorimetric color reproduction. Particularly, occurrence of a pseudo contour is a problem in the division method in the related art; in the embodiments of the invention, however, since the color conversion model of the image output unit 13 is formed without dividing the color gamut, smooth gradation representation with no occurrence of any pseudo contour is made possible.

FIG. 7 is a schematic representation of an example of

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a computer program for realizing the function of the color image

processing apparatus of the invention or the color image

processing method of the invention and storage media storing

the computer program. In the figure, numeral 101 denotes a

5   program, numeral 102 denotes a computer, numeral 111 denotes

a magneto-optical disk, numeral 112 denotes an optical disk,

numeral 113 denotes a magnetic disk, numeral 114 denotes memory,

numeral 121 denotes a magneto-optical disk unit, numeral 122

denotes an optical disk unit, and numeral 123 denotes a magnetic

10   disk unit.

The function of the color conversion section 24 described

in the embodiments or some or all of the components of the image

processing apparatus 12 other than the color conversion section

24 shown in FIG. 1 can be implemented as the program 101 that

15   can be executed by a computer. In this case, the program 101

and the data used by the program 101 can also be stored on a

storage medium that can be read by the computer. The storage

medium is a medium capable of causing a change state of energy

of magnetism, light, electricity, etc., to occur in a reader

20   installed in the hardware resources of the computer in response

to the program description and transmitting the program

description to the reader in the corresponding signal format,

such as the magneto-optical disk 111, the optical disk (including

a CD, a DVD, etc.,), the magnetic disk 113, or the memory 114

25   (including an IC card, a memory card, etc.,). Of course, the

storage media are not limited to portable media.

The program 101 is previously stored on the storage media and the storage medium is placed in the magneto-optical disk unit 121, the optical disk unit 122, or the magnetic disk unit

5   123 of the computer 102 or a memory slot (not show), for example, whereby the program 101 can be read from the computer 102 for executing the function of the color image processing apparatus of the invention or the color image processing method of the invention. Alternatively, a storage medium may be previously

10   installed in the computer 102 and the program 101 may be transferred to the computer 102 through a network, etc., for example, and stored in the storage medium for execution.

Of course, some functions can also be implemented as hardware or all functions may be implemented as hardware.

15   Alternatively, the system can be implemented as a program also containing the configuration of the original edit apparatus 11 or can also be implemented as one program together with a control program in the image output unit 13. Of course, to apply the program to any other application, the program can

20   also be integrated into one with the program in the application.

As apparent from the description given above, according to the embodiments of the invention, the (N-3) variables of the second color signal is determined from the first color signal including three variables. the remaining three variables of

25   the second color signal are determined on the basis of the

determined (N-3) variables of the second color signal and the first color signal so that the second color signal is colorimetrically equal to the first color signal. Particularly, from the first color signal, the (N-3) variables of the second

5   color signal such as the black amount and the solid color amount are determined from the range for making color reproduction possible in the color gamut found by solving the color conversion model of the image output unit using the numerical solution method and the achromatic UCR ratio and the chromatic UCR ratio

10   determined from the first color signal. Accordingly, the black amount and the solid color amount can be controlled as desired with respect to the first color signal considering the image quality of graininess, etc., and full use of the color gamut of the image output unit can be made.

15   Further, from the (N-3) variables of the second color signal thus determined and the first color signal, for example, the color conversion model of the image output unit is determined using the numerical solution method so that the remaining three variables of the image output unit becomes colorimetrically

20   equal to the first color signal, whereby it is made possible to ensure colorimetric color reproduction. Particularly, the division method to ensure colorimetric color reproduction in the related art involves the problem of occurrence of a pseudo contour. In the embodiments of the invention, however, since

25   the color conversion model of the image output unit is formed

without dividing the color gamut, smooth gradation representation with no occurrence of any pseudo contour is made possible.

Further, according to the embodiments of the invention, color conversion processing involving a large amount of computation can be previously performed to determine the color conversion parameter of a three-dimensional DLUT, and direct color conversion can be executed with the three-dimensional DLUT. Accordingly, it is made possible to accomplish color conversion at very high speed when actual color conversion processing is performed. If a hardware configuration is adopted for the invention, the configuration can be made simple because the computation amount is small.

Further, according to the embodiments of the invention, from the first color signal, the (N-3) variables of the second color signal is determined by performing a UCR processing of the achromatic component and the chromatic component, whereby it is made possible not only to control the black amount and the solid color amount considering the image quality, but also to determine the black amount and the solid color amount at high speed.